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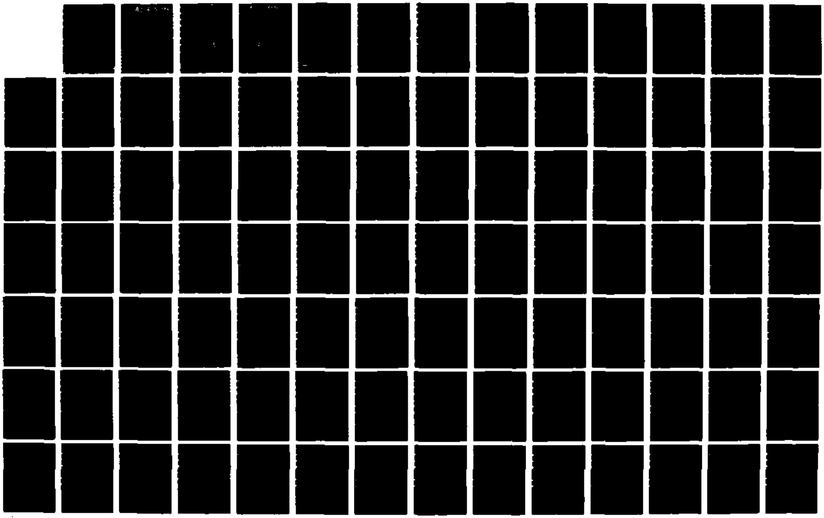

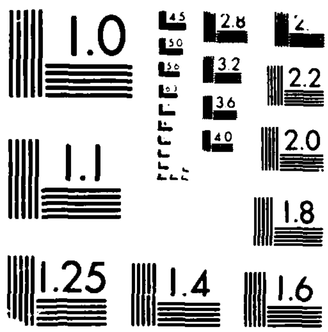

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AD-A190 366

TUTORIAL

TRACK II

ADVANCED ADA TOPICS

By

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and

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and

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This document contains prints of viewgraphs presented at the Advanced Ada Topics Tutorial, Track II June 9, 1987. Topics covered were: Data Abstraction, Tasking, Strong Typing, and Exceptions

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Ada Tasking*

Abstraction of Process

by

Dean W. Gonzalez

David A. Cook

303-472-2136
AV 259-2136

U.S. Air Force Academy

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ADA TASKING

- OVERVIEW

  DEFINE ADA TASKING

  DEFINE SYNCHRONIZATION MECHANISM

  EXAMPLES

- STARTED AFTER ELABORATION OF PARENT, AND BEFORE THE PARENT'S FIRST STATEMENT

- MAY ALSO BE A TYPE AND TREATED AS AN OBJECT

Ada Tasking

Task Definition

- A program unit for concurrent execution
- Never a Library Unit
- Master is a ...
  - Library Package
  - Subprogram
  - Block Statement
  - Other Task

Callee Provides Service

1. Immediate Response
2. Wait for a while
3. Wait forever

Service is Requested with an entry call statement

Service is provided with an accept statement

ADA TASKING

SYNCHRONIZATION MECHANISMS

- GLOBAL VARIABLES
- RENDEZVOUS

  MAIN PROGRAM IN A TASK

  CALLER REQUESTS SERVICE

  1. IMMEDIATE REQUEST
  2. WAIT FOR A WHILE
  3. WAIT FOREVER

ADA TASKING

SCENARIO I

"THE GOLDEN ARCHES"

MCD TASKS :

- SERVICE PROVIDED : FOOD
- SERVICE REQUESTED : NONE

GONZO TASKS :

- SERVICE PROVIDED : NONE
- SERVICE REQUESTED : FOOD

ADA TASKING

- SELECT STATEMENT PROVIDES ABILITY TO PROGRAM THE DIFFERENT 'REQUEST' AND 'PROVIDE' MODES
- GUARDS ARE "IF STATEMENTS" FOR THE PROVIDING SERVICE
- TERMINATION IS AN ALTERNATIVE IF A SERVICE IS NO LONGER NEEDED

```
Task McD is
   entry SERVE(TRAY_OF : out FOOD_TYPE);
end McD;

Task GONZO;

Task Body McD is
   NEW_TRAY : FOOD_TYPE;
   function COOK return FOOD_TYPE is.......
   begin
      loop
         accept SERVE (TRAY__OF : out FOOD_TYPE) do
            TRAY_OF := COOK;
         end;
      end loop;
   end McD;
```

```
Task Body GONZO is
   MY_TRAY : FOOD_TYPE;
   procedure CONSUME (MY_TRAY : in FOOD_TYPE) is ...
   begin
      loop
         McD.SERVE ( MY_TRAY );
         CONSUME (MY_TRAY);
      end loop;
   end GONZO;
```

```
Task Body McD is
   NEW_TRAY : FOOD_TYPE;


   function COOK return FOOD_TYPE is

      ...
   end COOK;


   begin
      loop
         NEW_TRAY := COOK;
         accept SERVE (TRAY_OF : out FOOD_TYPE ) do
            TRAY_OF := NEW_TRAY;
         end SERVE;

      end loop;
  end GONZO;
```

```
loop

   NEW_TRAY := COOK;
   select
      accept SERVE (TRAY_OF : out FOOD_TYPE) do...
         TRAY_OF := NEW_TRAY;
      end SERVE;
   else
      null;
   end select;

end loop;
```

```
loop

   NEW_TRAY := COOK;
   select
      accept SERVE (TRAY_OF : out FOOD_TYPE) do...
         TRAY_OF := NEW_TRAY;
      end SERVE;
   else
      terminate;
   end select;

end loop;
```

```
loop

   NEW_TRAY := COOK;
   select
      accept SERVE (TRAY_OF : out FOOD_TYPE) do...
         TRAY_OF := NEW_TRAY;
      end SERVE;
   or
      delay 15 * MINUTES;
   end select;

end loop;
```

```
loop

   select
      McD.SERVE(MY_ORDER); consume (MY_ORDER);
   else
      select
         BK.SERVE(MY_ORDER); consume (MY_ORDER);
      else
         exit;
      end select;
   end select;

end loop;
```

```
loop
   select
      McD.SERVE(MY_ORDER);  consume (MY_ORDER);
   or
      delay 10.0 * MINUTES;
      select
         BK.SERVE(MY_ORDER);  consume (MY_ORDER);
      or
         delay 5.0 * MINUTES;
         exit;
      end select;
   end select;
end loop;
```

```
loop

   select
      McD.SERVE (MY_ORDER);
   or
      BK.SERVE (MY_ORDER);
   end select;

   consume;

end loop;
```

```
loop

   select
      McD.SERVE (MY_ORDER);
   or
      BK.SERVE (MY_ORDER);

   else
      delay 10 * MINUTES;
      exit;
   end select;

   consume;


end loop;
```

ADA TASKING

SCENARIO II

"NO FREE LUNCH"

McD TASK

SERVICE PROVIDED : FOOD
SERVICE REQUESTED: MONEY

GONZO TASK

SERVICE PROVIDED : MONEY
SERVICE REQUESTED: FOOD

```
Task McD is
   entry SERVE ( ORDER : out FOOD_TYPE;
                 COST  : in  MONEY_TYPE);
end McD;

TASK GONZO;
```

--OR

```
Task McD is
   entry SERVE ( ORDER : out FOOD TYPE):
end McD;


Task GONZO is
   entry PAY ( COST    :  in MONEY_TYPE;
               PAYMENT : out MONEY_TYPE);
end GONZO;
```

```
Task Body McD is
     CASH_DRAWER : MONEY_TYPE;
     NEW_ORDER   : FOOD_TYPE;
     function COOK .................
     function CALC_COST (ORDER : in FOOD_TYPE )
              return MONEY_TYPE is ........
   begin
     loop
        NEW_ORDER := COOK;
        select
           accept SERVE(ORDER : out FOOD_TYPE) do
              ORDER := NEW_ORDER:
              COST := CALC_COST (NEW_ORDER);
              GONZO_PAY (COST, AMOUNT_PAID);
              CASH_DRAWER := CASH_DRAWER + AMOUNT_PAID;
              end SERVE;
         or
              delay 15.0 * MINUTES;
        end select;
     end loop;
 end McD;
```

```
Task Body GONZO is
        ACCOUNT_BALANCE : MONEY_TYPE;
        MY_ORDER : FOOD_TYPE;
        function GO_TO_WORK return MONEY_TYPE is....
    begin
        ACCOUNT_BALANCE := GO_TO_WORK + ACCOUNT_BALANCE;
        loop
           McD.SERVE (MY_ORDER);
           accept PAY (COST    : in MONEY_TYPE;
                       PAYMENT : out MONEY_TYPE) do
              ACCOUNT_BALANCE := ACCOUNT_BALANCE -
                                   COST ;
              PAYMENT := COST;
           end PAY;
        end loop;
    end GONZO;
```

ADA TASKING

SCENARIO II A

"NO WAIT FOR THE WAITERS"

MCD TASK

SERVICE PROVIDED : FOOD
SERVICE REQUESTED: MONEY

GONZO TASK

SERVICE PROVIDED : MONEY
SERVICE REQUESTED: FOOD

MANAGER TASK

SERVICE PROVIDED : MAKE NEW WAITER
SERVICE REQUESTED: NONE

```
Task type McD is
    entry SERVE....
end McD;

Task GONZO is
    entry PAY....
end GONZO;

Task MANAGER;

Type CASHIER_POINTER is access McD;

Type REGISTER_TYPE is array (1..NO_REGISTERS)
                    of CASHIER_POINTER;

THE_REGISTERS : REGISTER_TYPE:=(others => new McD);
```

```
Task Body McD is
  ...
  ...
  ...
  begin
   loop
    NEW_ORDER := COOK;
    select
       accept SERVE.....
       ...
       end SERVE;
     or
       delay 2.0 * MINUTES;
       exit;
     end select;
   end loop;
```

```
Task Body GONZO is
   ...
   ...
   begin
     ...
     ...
     --Now, GONZO has to search for the open
     --  registers, and select the one with
     --  the shortest line
     ...
     ...
     THE_REGISTERS(MY_REGISTER).SERVE;
     ...
   end GONZO;
```

```
Task Body MANAGER is
  ...

  ...
  begin
    loop
   --The MANAGER will look at the queue lengths of
   --  the open registers, and, when necessary
   --  will open registers that are currently
   --  closed
   ...
      if ............ then
        THE_REGISTERS(CLOSED_REGISTER) := new McD;
      end if;
    end loop;
end MANAGER;
```

Ada Tasking

Scenario III

"A Sugar Cone, Please:

BR Task
- Service Provided : Ice Cream
- Service Requested: An Order

Servomatic Task
- Service Provided : A Number

Customers Task
- Service Provided : An Order
- Service Requested: Ice Cream

```
task BR is
   entry SERVE (ICE_CREAM : out DESSERT_TYPE);
end BR;

task SERVOMATIC is
   entry TAKE (A_NUMBER : out SERVOMATIC_NUMBERS);
end SERVOMATIC;

task type CUSTOMER_TASK is
   entry REQUEST (ORDER : out ORDER_TYPE);
end CUSTOMER_TASK;

type CUSTOMER is access CUSTOMER_TASK;

CUSTOMERS : array (SERVOMATIC_NUMBERS) of CUSTOMER;
```

```
task body BR
     NEXT_CUSTOMER : SERVOMATIC_NUMBERS :=
                SERVOMATIC_NUMBERS'last;
     CURRENT_ORDER : ORDER_TYPE;
     ICE_CREAM : DESSERT_TYPE;
     function MAKE (ORDER : in ORDER_TYPE) return
                             DESSERT_TYPE is......
  begin
     loop
        begin
           NEXT_CUSTOMER := (NEXT_CUSTOMER + 1)
                        mod SERVOMATIC_NUMBERS'last;
           CUSTOMERS(NEXT_CUSTOMER).REQUEST
                                 (CURRENT_ORDER);
           ICE_CREAM := MAKE(CURRENT_ORDER);
           accept SERVE(ICE_CREAM : out DESSERT_TYPE) do
                 ICE_CREAM := BR.ICE_CREAM;
           end SERVE;
        exception
           when TASKING_ERROR => null;
                 --customer not here
        end;
     end loop;
  end;
```

```
task body SERVOMATIC is
        NEXT_NUMBER : SERVOMATIC_NUMBERS :=
                               SERVOMATIC_NUMBERS'first;
    begin
        loop
            accept TAKE(A_NUMBER : out SERVOMATIC_NUMBERS) do
                A_NUMBER := NEXT_NUMBER;
            end TAKE;
            NEXT_NUMBER := (NEXT_NUMBER + 1) mod
                                          SERVOMATIC_NUMBERS'last;
        end loop;
    end SERVOMATIC;
```

```
task body CUSTOMER_TASK is
     MY_ORDER : ORDER_TYPE := ... --some value;
     MY_DESSERT : DESSERT_TYPE;
  begin
     accept REQUEST ( ORDER : out ORDER_TYPE) do
          ORDER := MY_ORDER;
     end REQUEST;
     BR.SERVE(MY_DESSERT);
     --eat the dessert, or do whatever
  end;
```

ADA TASKING

SCENARIO IV

"LETS HIDE THE SPOOLER TASK"

PRINTER_PACKAGE
ACTION-"HIDES" THE PRINT SPOOLER
BY RENAMING TASK ENTRY

SPOOLER TASK
SERVICE PROVIDED : VIRTUAL PRINT
SERVICE REQUESTED: PHYSICAL PRINT

PRINTER TASK
SERVICE PROVIDED : PHYSICAL PRINT
SERVICE REQUESTED: FILE NAME

```
Package PRINTER_PACKAGE is
   ...
   ...
   task SPOOLER is
      entry PRINT_FILE (NAME : in STRING;
                        PRIORITY : in NATURAL);
      entry PRINTER_READY;
   end SPOOLER;
   ...
   ...
   procedure PRINT ( NAME : in STRING;
                     PRIORITY : in NATURAL := 10)
      renames SPOOLER.PRINT_FILE;
end PRINTER_PACKAGE;


Package Body PRINTER_PACKAGE is
   ...
   ...
   task PRINTER is
      entry PRINT_FILE (NAME : in STRING );
   end PRINTER;
   ...
   ...
end PRINTER_PACKAGE;
```

```
task body SPOOLER is
    begin
      loop
       select
          accept PRINTER_READY do
             PRINTER.PRINT_FILE ( REMOVE (QUEUE)  );
             -- Remove would determine the next job and
             --    send it to the actual printer
          end PRINTER_READY;
       else
          null;
       end select;
       select
          accept PRINT_FILE ( NAME : in STRING;
                              PRIORITY : NATURAL ) do
             INSERT ( NAME, PRIORITY);
             --put name on queue or queues according
             --   to priority
          end PRINT_FILE;
        else
           null;
        end select;
     end select;
    end loop;
end SPOOLER;
```

```
task body PRINTER is
   begin
      loop
         SPOOLER.PRINTER_READY;
         accept PRINT_FILE ( NAME : in STRING ) do

            if NAME'length /= 0 then ........

               --print the file

            else
               delay 10.0 * seconds;
            end if;

          end PRINT_FILE;
       end loop;
   end PRINTER;
```

```
with PRINTER_PACKAGE;
procedure MAIN is
     .
     .
     .
     loop
          --process several files
          PRINTER_PACKAGE.PRINT (A_FILE, A_PRIORITY);
          .
          .
     end loop;
end MAIN;
```

APPLICATIONS FOR TASKS

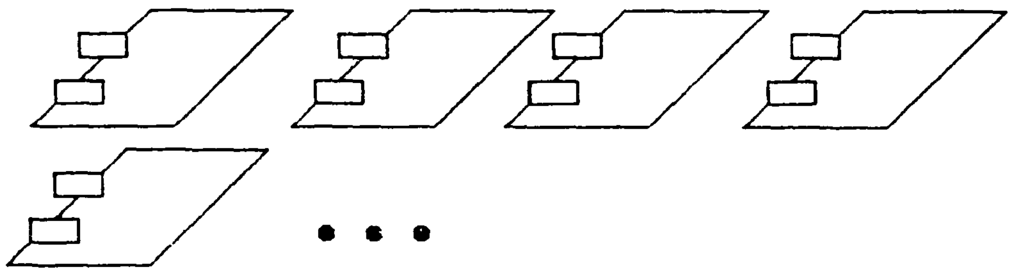
- CONCURRENT OPERATIONS
- ROUTING MESSAGES
- SHARED RESOURCE MANAGEMENT
- INTERRUPT HANDLING

MATRIX MULTIPLICATION

$$\begin{bmatrix} 1 & 1 & 1 \\ 2 & 2 & 0 \end{bmatrix} * \begin{bmatrix} 2 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 4 \\ 6 \end{bmatrix}$$

```
type ROW_OR_COL is array (integer range <>) of integer;
type PTR is access ROW_OR_COL;

task type PARTIAL is
   entry SEND  (ROW, COL : ROW_OR_COL);
   entry RECEIVE (RESULT : out integer);
end PARTIAL;
```

MAIN



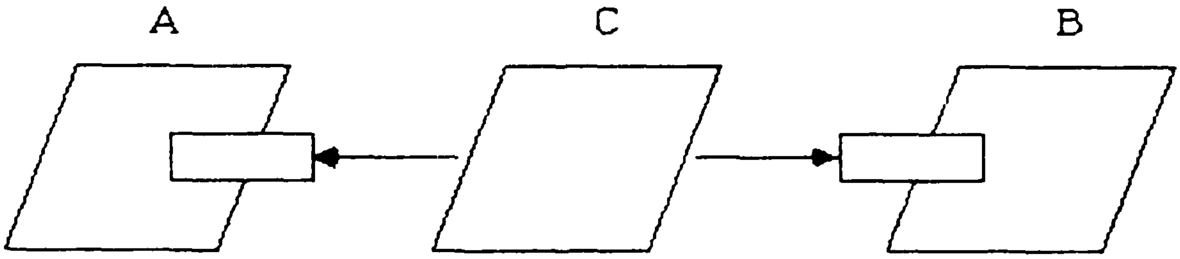
```
begin
  -- send row and col
  -- receive partial product
end
```

```
task body PARTIAL is

    PRODUCT : integer := 0;
    ROW_PTR : PTR;
    COL_PTR : PTR;

begin

    accept SEND (ROW,COL : ROW_OR_COL) do
        ROW_PTR := new ROW_OR_COL'(ROW);
        COL_PTR  := new ROW_OR_COL'(COL);
    end SEND;

    for I in ROW_PTR.all'range
    loop
       PRODUCT := PRODUCT +
                  ROW_PTR(I) * COL_PTR(I);
    end loop;

    accept RECEIVE (RESULT : out integer) do
        RESULT := PRODUCT;
    end RECEIVE;

end PARTIAL;
```

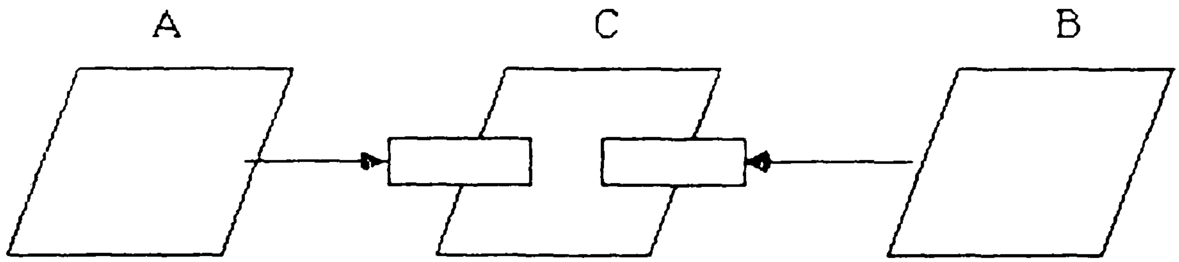
```
procedure MAIN is

 COLS : constant := 10;
 ROWS : constant := 10;
 type MATRIX is array (1 .. ROWS) of
                               ROW_OR_COL (1 .. COLS);

 MAT : MATRIX;
 VECTOR : ROW_OR_COL (1 .. COLS);
 FINAL    : ROW_OR_COL (1 .. ROWS);

 . . .
 declare

    WORKER : array (1 .. ROWS) of PARTIAL;  -- tasks

 begin
   for I in 1 .. ROWS
   loop
       WORKER(I).SEND(ROW => MAT(I),
                      COL => VECTOR);
   end loop;

   for I in 1 .. ROWS
   loop
       WORKER(I).RECEIVE (FINAL(I));
   end loop;

end;        -- block
. . .
```

ROUTING MESSAGES

- WRITE TASK SPECIFICATIONS TO SEND AN INTEGER FROM TASK A TO TASK B

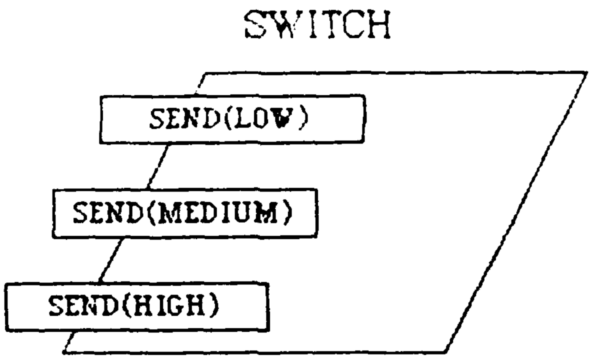


- WRITE SPECIFICATIONS AND BODIES FOR THE FOLLOWING SYSTEM. TASK C WILL REPEATEDLY GET AN INTEGER FROM TASK A AND SEND IT ON TO TASK B



PRIORITY MESSAGES

```
type PRIORITY is (LOW, MEDIUM, HIGH);

task SWITCH is
   entry SEND (PRIORITY)
          (M : in string);
end SWITCH;
```




```
task body SWITCH is
begin
  loop
    select

      accept SEND(HIGH) do . . . end SEND;

    or

      when SEND(HIGH)'count = 0 =>
      accept SEND(MEDIUM) do  . . . end SEND;

    or

      when SEND(HIGH)'count = 0 and
             SEND(MEDIUM)'count = 0 =>
      accept SEND (LOW) . . . end SEND;

    end select;
  end loop;
end SWITCH;
```

A Synchronizing Buffer

```
task SYNCHRONIZER is
  entry PUT (ITEM : in SOME_TYPE);
  entry GET (ITEM : out SOME_TYPE);
end SYNCHRONIZER;

task body SYNCHRONIZER is

   SPOT : SOME_TYPE;

begin

  loop

       accept PUT (ITEM : in SOME_TYPE) do
            SPOT := ITEM;
       end PUT;

       accept GET (ITEM : out SOME_TYPE) do
             ITEM := SPOT;
       end GET;

    end loop;

end SYNCHRONIZER;
```

CONTROLING RESOURCES

- SEVERAL CONCERNS ARE PRESENT WHEN DEALING WITH PARALLELISM THAT ARE NOT PRESENT WHEN DEALING IN A PURELY SEQUENTIAL MODE

- IT IS IMPORTANT TO BE ABLE TO ASSURE THAT A VALUE IS NOT BEING CHANGED BY ONE USER AT THE PRECISE MOMENT THAT IT IS BEING REFERENCED BY ANOTHER USER

- Ada PROVIDES A PRAGMA 'SHARED' WHICH CAN HELP

```
INDEX : integer;
pragma SHARED(INDEX);
```

- ENFORCES MUTUALLY EXCLUSIVE ACCESS

- AVAILABLE FOR SCALAR AND ACCESS TYPES ONLY

SEMAPHORES

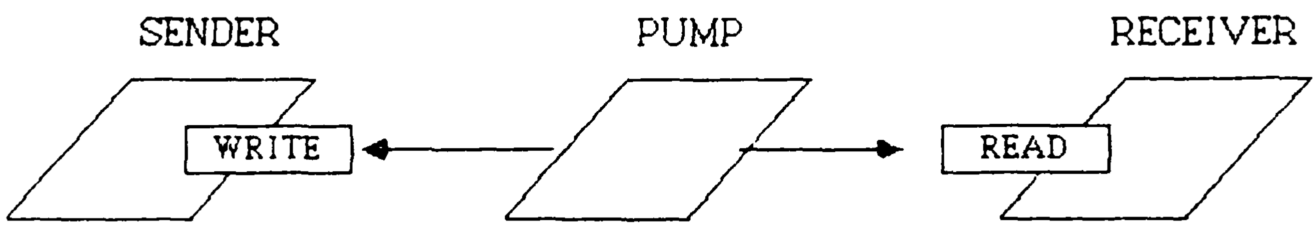
```
task SEMAPHORE is
     entry SEIZE;
     entry RELEASE;
end SEMAPHORE;

task body SEMAPHORE is
  IN_USE : boolean := false;
begin
  loop
     select

        when not IN_USE =>
        accept SEIZE do
             IN_USE := true;
        end SEIZE;

     or

        when IN_USE =>
        accept RELEASE do
             IN_USE := false;
        end RELEASE;

     end select;
  end loop;
end SEMAPHORE;
```

ENCAPSULATING A DATA ITEM

```
task PROTECTED is
     entry SET (OBJ : in integer);
     entry GET (OBJ : out integer);
end PROTECTED;

task body PROTECTED is
     LOCAL : integer;
begin
  loop
     select
          accept SET (OBJ : in integer) do
               LOCAL := OBJ;
          end SET;
     or
          accept GET (OBJ : out integer) do
               OBJ := LOCAL;
          end GET;
     end select;
  end loop;
end PROTECTED;
```

PUMPING TASK

```
task PUMP;

task SENDER is
   entry WRITE (ITEM : out SOME_TYPE);
end SENDER;

task RECEIVER is
   entry READ (ITEM : in SOME_TYPE);
end RECEIVER;

task body PUMP is
   THE_ITEM : SOME_TYPE;
begin
   loop
      SENDER.READ(THE_ITEM);
      RECEIVER.WRITE(THE_ITEM);
   end loop;
end PUMP;

task body SENDER is separate;
task body RECEIVER is separate;
```



HARDWARE INTERRUPTS

- FOR ARCHITECTURES THAT 'JUMP' TO A CERTAIN HARDWARE ADDRESS UPON RECEIPT OF AN INTERRUPT
- A TASK ENTRY IS ASSOCIATED WITH THE ADDRESS
- PRIORITY IS HIGHER THAN ANY USER-DEFINED

```
task INTERRUPT_HANDLER is
   entry DONE;
   for DONE use at 16#40#;
end INTERRUPT_HANDLER;


task body INTERRUPT_HANDLER is
  begin
    accept DONE do
       ...
    end DONE;
  end INTERRUPT_HANDLER;
```

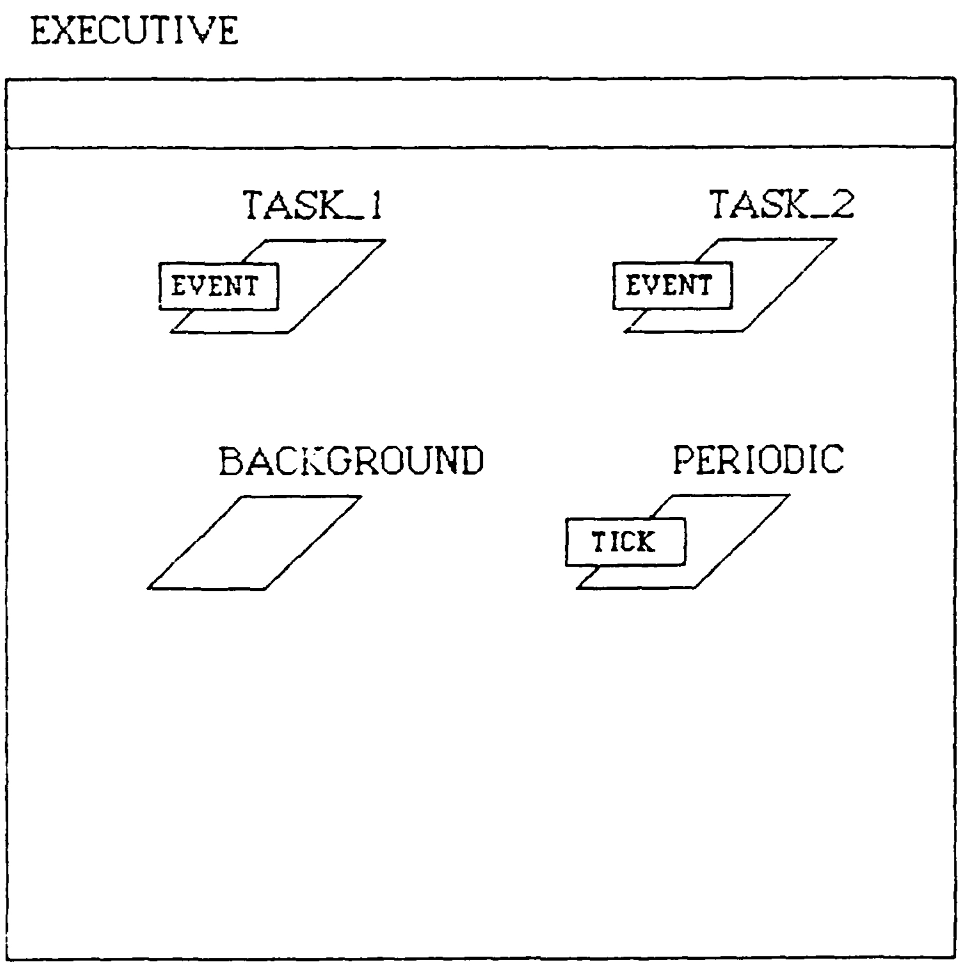
EVENT DRIVEN SYSTEMS W/BACKGROUND

- A cyclic executive might deal with several levels of processing

  -- Event driven processing (high priority, perhaps interrupt handling)

  -- Periodic (cyclic) processing

  -- Background processing (low priority)



```
procedure EXECUTIVE is

    task TASK_1 is
        pragma PRIORITY (10);
        entry EVENT;
    end TASK_1;

    task TASK_2 is
        entry EVENT;
        for EVENT use at 16#110#;
    end TASK_2;

    task BACKGROUND is
        pragma PRIORITY (0);
    end BACKGROUND;

    task PERIODIC is
        pragma PRIORITY (5);
        entry TICK;              -- one tick per cycle
    end PERIODIC;

    task body PERIODIC is
        ...
    begin
        loop
            accept TICK;
            ... -- process a frame
        end loop;
    end PERIODIC;

    -- bodies (or stubs) of other tasks go here

end EXECUTIVE;
```

Second Annual ASEET Symposium

Tutorial on Ada® Exceptions

by
Major Patricia K. Lawlis

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Air Force Institute of Technology (AFIT)
and
Arizona State University (ASU)

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Outline

=> Overview

- Naming an exception
- Creating an exception handler
- Raising an exception
- Handling exceptions
- Turning off exception checking
- Tasking exceptions
- More examples

Overview

- What is an exception

- Ada exceptions

- Comparison

    - the American way

    - using exceptions

What Is an Exception

- A run time error
- An unusual or unexpected condition
- A condition requiring special attention
- Other than normal processing

Ada Exceptions

- An exception has a name
  - may be predefined
  - may be declared
- The exception is raised
  - may be raised implicitly by run time system
  - may be raised explicitly by **raise** statement
- The exception is handled
  - exception handler may be placed in any **frame**
  - exception propagates until handler is found
  - if no handler anywhere, process aborts

The American Way

```
package Stack_Package is

        type Stack_Type is limited private;

        procedure Push (Stack : in out Stack_Type;
                        Element : in Element_Type;
                        Overflow_Flag : out boolean);
        ...

end Stack_Package;


with Text_IO;
with Stack_Package; use Stack_Package;
procedure Flag_Waving is
        ...
        Stack : Stack_Type;
        Element : Element_Type;
        Flag : boolean;
begin
        ...
        Push (Stack, Element, Flag);
        if Flag then
                Text_IO.Put ("Stack overflow");
                ...
        end if;
        ...
end Flag_Waving;
```

Using Exceptions

```
package Stack_Package is

        type Stack_Type is limited private;
        Stack_Overflow,
        Stack_Underflow : exception;

        procedure Push (Stack : in out Stack_Type;
                        Element : in Element_Type);
                  -- may raise Stack_Overflow
        ...
end Stack_Package;


with Text_IO;
with Stack_Package; use Stack_Package;
procedure More_Natural is
        ...
        Stack : Stack_Type;
        Element : Element_Type;
begin
        ...
        Push (Stack. Element);
        ...
exception
        when Stack_Overflow =>
                Text_IO.Put ("Stack overflow");
        ...
end More_Natural;
```

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Naming an Exception

- Predefined exceptions
- Declaring exceptions
- I/O exceptions

Predefined Exceptions

- In package STANDARD (also see chap 11 of LRM)

- CONSTRAINT_ERROR

  violation of range, index, or discriminant constraint...

- NUMERIC_ERROR

  execution of a predefined numeric operation cannot deliver a correct result

- PROGRAM_ERROR

  attempt to access a program unit which has not yet been elaborated...

- STORAGE_ERROR

  storage allocation is exceeded...

- TASKING_ERROR

  exception arising during intertask communication

Declaring Exceptions

exception_declaration ::= identifier_list : **exception**;

- *Exception may be declared anywhere an object declaration* is appropriate

- However, exception is not an object

  - may not be used as subprogram parameter, record or array component

  - has same scope as an object, but its effect may extend beyond its scope

Example:

```
procedure  Calculation  is

        Singular : exception;
        Overflow, Underflow : exception;

begin
    ...
end  Calculation;
```

I/O Exceptions

- Exceptions relating to file processing

- In predefined library unit IO_EXCEPTIONS
  (also see chap 14 of LRM)

- TEXT_IO, DIRECT_IO, and SEQUENTIAL_IO **with** it

```
package IO_EXCEPTIONS is

        NAME_ERROR    : exception;
        USE_ERROR     : exception;     --attempt to use
                                       --invalid operation
        STATUS_ERROR  : exception;
        MODE_ERROR    : exception;
        DEVICE_ERROR  : exception;
        END_ERROR     : exception;     --attempt to read
                                       --beyond end of file
        DATA_ERROR    : exception;     --attempt to input
                                       --wrong type
        LAYOUT_ERROR  : exception;     --for text processing

end IO_EXCEPTIONS;
```

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Creating an Exception Handler

- Defining an exception handler
- Restrictions
- Handler example

Defining an Exception Handler

- Exception condition is "caught" and "handled" by an exception handler

- Exception handler may appear at the end of any frame (block, subprogram, package or task body)

```
begin
    ...
exception
    -- exception handler(s)
end;
```

- Form similar to case statement

exception_handler ::=
    when exception_choice {| exception_choice} **=>**
        sequence_of_statements

exception_choice ::= exception_name | **others**

Restrictions

- Exception handlers must be at the end of a frame

- Nothing but exception handlers may lie between **exception** and **end** of frame

- A handler may name any visible exception declared or predefined

- A handler includes a sequence of statements

    - response to exception condition

- A handler for **others** may be used

    - must be the last handler in the frame

    - handles all exceptions not listed in previous handlers of the frame (including those not in scope of visibility)

    - can be the only handler in the frame

Handler Example

```
procedure Whatever is

        Problem_Condition : exception;

begin
        ...

exception

        when Problem_Condition =>
                Fix_It;

        when CONSTRAINT_ERROR =>
                Report_It;

        when others =>
                Punt;

end Whatever;
```

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=> **Raising an exception**

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Raising an Exception

- How exceptions are raised
- Effects of raising an exception
- Raising example

How Exceptions are Raised

- Implicitly by run time system

  - predefined exceptions

- Explicitly by **raise** statement

raise_statement ::= **raise** [exception_name];

  - the name of the exception must be visible at the point of the raise statement

  - a raise statement without an exception name is allowed only within an exception handler

Effects of Raising an Exception

- Control transfers to exception handler at end of frame
  (if one exists)

- Exception is lowered

- Sequence of statements in exception hander is executed

- Control passes to end of frame

- If frame does not contain an appropriate exception handler,
  the exception is propagated

Raising Example

```
procedure Whatever is

        Problem_Condition  : exception;
        Real_Bad_Condition : exception;

begin
        ...
        if Problem_Arises then
                raise Problem_Condition;
        end if;
        ...
        if Serious_Problem then
                raise Real_Bad_Condition;
        end if;
        ...
exception

        when Problem_Condition =>
                Fix_It;

        when CONSTRAINT_ERROR =>
                Report_It;

        when others =>
                Punt;

end Whatever;
```

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=> **Handling exceptions**

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Handling Exceptions

- How exception handling can be useful
- Which exception handler is used
- Sequence of statements in exception handler
- Propagation
- Propagation example

How Exception Handling Can Be Useful

- Normal processing could continue if
  - cause of exception condition can be "repaired"
  - alternative approach can be used
  - operation can be retried
- Degraded processing could be better than termination
  - for example. safety-critical systems
- If termination is necessary, "clean-up" can be done first

Which Exception Handler Is Used

- If exception is raised during normal execution, system looks for an exception handler at the end of the frame in which the exception occurred

- If exception is raised during elaboration of the declarative part of a frame

  - elaboration is abandoned and control goes to the end of the frame with the exception still raised

  - exception part of the frame is not searched for an appropriate handler

  - effectively, the calling unit will be searched for an appropriate handler

  - if elaboration of library unit, program execution is abandoned
    - -- all library units are elaborated with the main program

- If exception is raised in exception handler

  - handler may contain block(s) with handler(s)

  - if not handled locally within handler, control goes to end of frame with exception raised

Sequence of Statements in Exception Handler

- Handler completes the execution of the frame
  - handler for a **function** should usually contain a **return** statement
- Statements can be of arbitrary complexity
  - can use most any language construct that makes sense in that context
  - cannot use **goto** statement to transfer into a handler
  - if handler is in a block inside a loop, could use **exit** statement
- Handler at end of package body applies only to package initialization

Propagation

- Occurs if no handler exists in frame where exception is raised

- Also occurs if **raise** statement is used in handler

- Exception is propagated dynamically

  - propagates from subprogram to unit calling it (not necessarily unit containing its declaration)

  - this can result in propagation outside its scope

- Propagation continues until

  - an appropriate handler is found

  - exception propagates to main program (still with no handler) and program execution is abandoned

Propagation Example

```
procedure Do_Nothing is
    --------------
    procedure Has_It is
        Some_Problem : exception;
    begin
        ...
        raise Some_Problem;
        ...
    exception
        when Some_Problem =>
            Clean_Up;
            raise;
    end Has_It;
    --------------
    procedure Calls_It is
    begin
        ...
        Has_It;
        ...
    end Calls_It;
    --------------
begin  -- Do_Nothing
    ...
    Calls_It;
    ...
exception
    when others => Fix_Everything;
end Do_Nothing;
```

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Turning Off Exception Checking

- Overhead vs efficiency
- Pragma SUPPRESS
- Check identifiers

Overhead vs Efficiency

- Exception checking imposes run time overhead

  - interactive applications will never notice
  - real-time applications have legitimate concerns but must not sacrifice system safety

- When efficiency counts

  - first and foremost, make program work
  - be sure possible problems are covered by exception handlers
  - check if efficient enough - stop if it is
  - if not, study execution profile
    - -- eliminate bottlenecks
    - -- improve algorithm
    - -- avoid "cute" tricks
  - check if efficient enough - stop if it is
  - if not, trade-offs may be necessary
  - some exception checks may be expendable since debugging is done
  - however, every suppressed check poses new possibilities for problems
    - -- must re-examine possible problems
    - -- must re-examine exception handlers
  - always keep in mind
    - -- problems <u>will</u> happen
    - -- critical applications must be able to deal with these problems

Moral

Improving the algorithm is far better - and easier in the long run - than suppressing checks

Pragma SUPPRESS

- *Only allowed immediately within a declarative part or* immediately within a package specification

pragma SUPPRESS (identifier [,[**ON** =>] name]);

- identifier is that of the check to be omitted (next slide lists identifiers)

- *name* is that of an object, type, or unit for which the check is to be suppressed

  -- if no name is given, it applies to the remaining declarative region

- An implementation is free to ignore the suppress directive for any check which may be impossible or too costly to suppress

Example:

```
pragma SUPPRESS (INDEX_CHECK, ON => Index);
```

Check Identifiers

- These identifiers are explained in more detail in chap 11 of the LRM

- Check identifiers for suppression of CONSTRAINT_ERROR checks

  ACCESS_CHECK
  DISCRIMINANT_CHECK
  INDEX_CHECK
  LENGTH_CHECK
  RANGE_CHECK

- Check identifiers for suppression of NUMERIC_ERROR checks

  DIVISION_CHECK
  OVERFLOW_CHECK

- Check identifier for suppression of PROGRAM_ERROR checks

  ELABORATION_CHECK

- Check identifier for suppression of STORAGE_ERROR check

  STORAGE_CHECK

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=> **Tasking exceptions**

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Tasking Exceptions

- Exception handling is trickier for tasks
- Exceptions during task rendezvous
- Tasking example

Exception Handling Is Trickier for Tasks

- Rules are not really different, just more involved
    - local exceptions handled the same within frames

If exception is raised

- during elaboration of task declarations
    - the exception TASKING_ERROR will be raised at the *point of task activation*
    - the task will be marked completed
- during execution of task body (and not resolved there)
    - task is completed
    - exception is <u>not</u> propagated
- during task rendezvous
    - this is the really tricky part

Exceptions During Task Rendezvous

- If the **called** task terminates abnormally

  exception TASKING_ERROR is raised in **calling** task at the point of the entry call

- If the **calling** task terminates abnormally

  no exception propagates to the **called** task

- If an exception is raised in **called** task within an **accept** (and not handled there locally)

  the same exception is raised in the **calling** task at the point of the entry call
  (even if exception is later handled outside of the accept in the called task)

- If an entry call is made for entry of a task that becomes completed before accepting the entry

  exception TASKING_ERROR is raised in **calling** task at the point of the entry call

Tasking Example

```
procedure  Critical_Code  is

        Failure : exception;
         -------------
        task  Monitor  is
                entry Do_Something;
        end Monitor;
        task  body  Monitor  is
        ...
        begin
                accept  Do_Something   do
                        ...
                        raise  Failure;
                        ...
                end   Do_Something;
                ...
        exception   -- exception handled here
                when Failure =>
                        Termination_Message;
        end Monitor;
        -------------
begin  -- Critical_Code
        ...
        Monitor.Do_Something;
        ...
exception   -- same exception will be handled here
        when Failure =>
                Critical_Problem_Message;

end   Critical_Code;
```

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=> **More examples**

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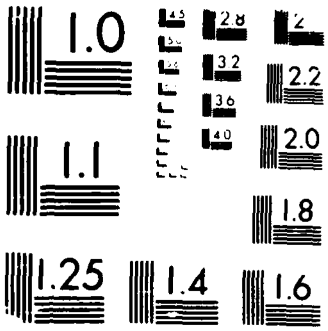

MICROCOPY RESOLUTION TEST CHART

[illegible] TANDARDS 1963 A

Interactive Data Input

```
with Text_io; use Text_io;
procedure Get_Input (Number : out integer) is

        type Input_Type is integer range  0..100;
        package Int_io is new Integer_io (Input_Type);
        In_Number : Input_Type;

begin  -- Get_Input

        loop              -- to try again after incorrect input

                begin  -- inner block to hold exception handler

                        put ("Enter a number 0 to 100");
                        Int_io.get (In_Number);
                        Number := In_Number;
                        exit;  -- to exit loop after correct input

                exception
                        when DATA_ERROR | CONSTRAINT_ERROR =>
                                put ("Try again, fat fingers!");
                                Skip_Line;    -- must clear buffer

                end;  -- inner block

        end  loop;

end  Get_Input;
```

Propagating Exception Out of Scope and Back In

```
declare
        package Container is
                procedure Has_Handler;
                procedure Raises_Exception;
        end Container;
          ----------
        procedure Not_in_Package is
        begin
                Container.Raises_Exception;
        exception
                when others => raise;
        end  Not_in_Package;
          ----------
        package  body  Container  is
                Crazy : exception;
                procedure  Has_Handler  is
                begin
                        Not_in_Package;
                exception
                        when Crazy => Tell_Everyone;
                end  Has_Handler;
                procedure   Raises_Exception  is
                begin
                        raise Crazy;
                end   Raises_Exception;
        end Container;
begin
        Container.Has_Handler;
end;
```

Keeping a Task Alive

```
task Monitor is
    entry Do_Something;
end Monitor;

task body Monitor is
begin
    loop        -- for never-ending repetition
        ...
        select
            accept Do_Something do

                begin  -- block for exception handler
                    ...
                    raise Failure;
                    ...
                exception
                    when Failure => Recover;
                end;  -- block

            end Do_Something;  -- exception must be
                               -- lowered before exiting
            ...
        end select;
        ...
    end  loop;

exception
    when others =>
        Termination_Message;
end Monitor;
```

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